



“Core” GV and Science Requirements in the Post-Launch Era



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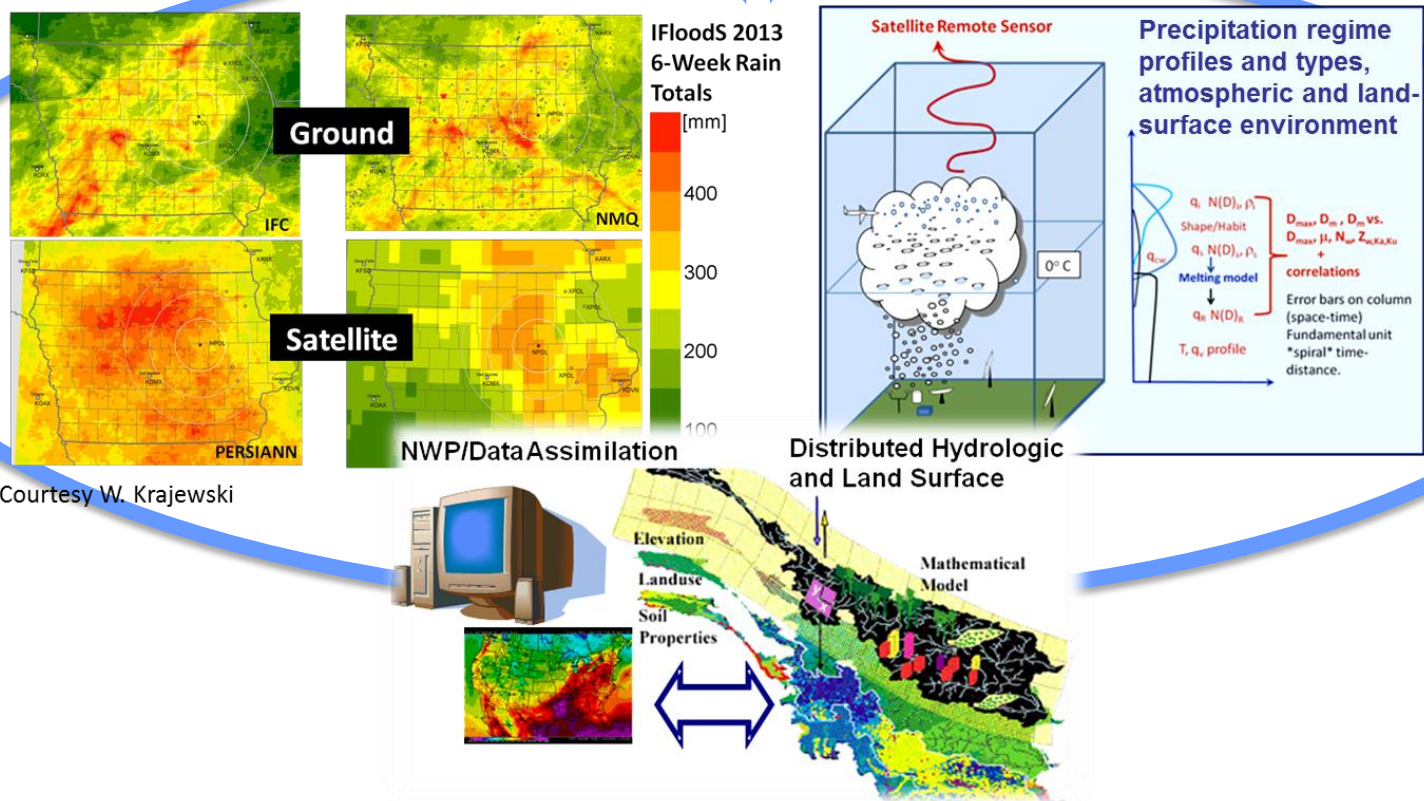
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**L1 Science Requirements
Continued Science Themes**

*Acknowledgements: L1 Requirements
WG, also P. Kirstetter, J. Wang, D. Wolff,
R. Morris, S. Nesbitt, P. Gatlin, J. Tan, D.
Moiseev, A. VonLerber*

"Core" Science Framework

Convergence, Physical Consistency, Utility



Courtesy W. Krajewski

Approaches

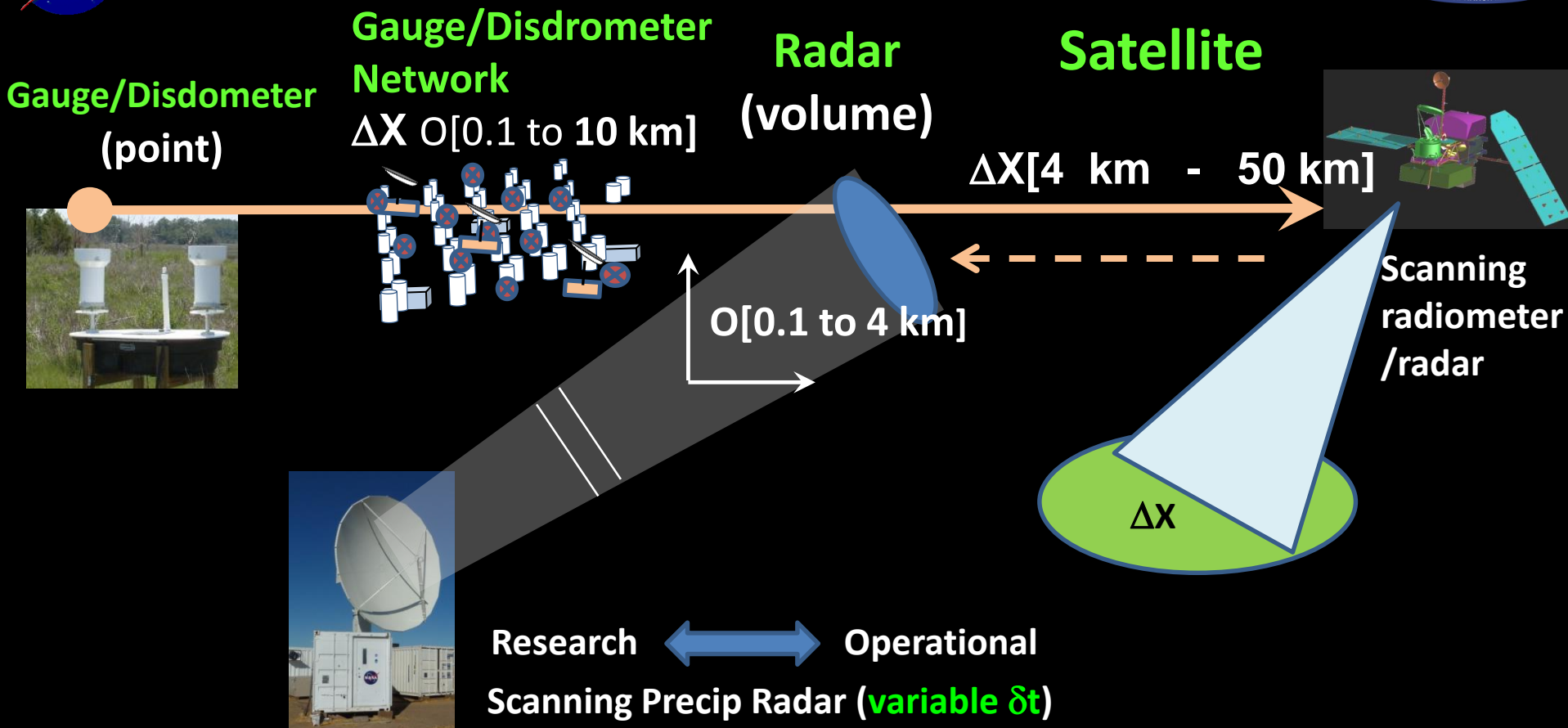
- **Direct:** National network comparisons-(Uncertainty- What/Where/When)
- **Physical:** Understand/Assess/improve (algorithm physical assumptions)
- **Integrated:** Impacts/utility with uncertainties (e.g., weather, climate, hydrology)



Measurements are required at a multitude of scales



Radars function as a spatial/temporal “BRIDGE”

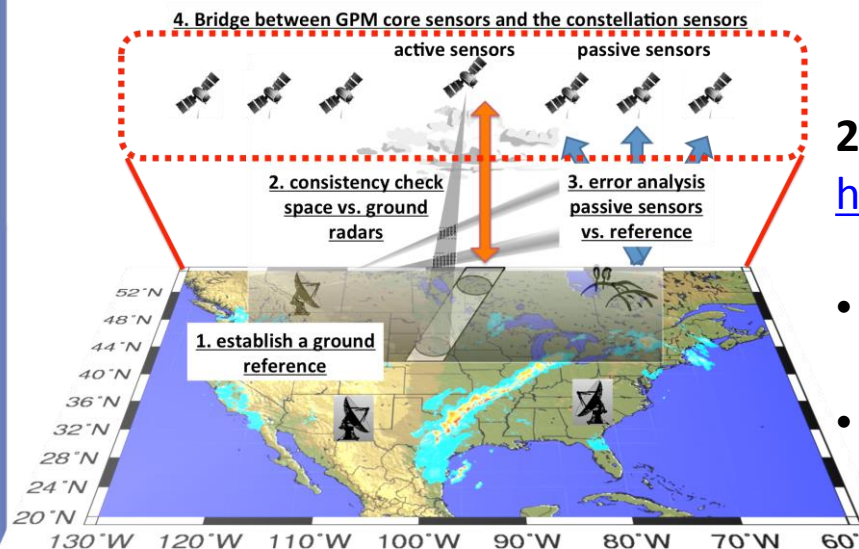


- Synergistic and adaptive 4-D use of relevant platforms
 - long term, “heart beat”, statistical sampling (national radar network)
 - Ability to “probe” at high space-time res. (research radars)
 - Reference to ground measurements (gauge and disdrometer networks)

GPM “Core” Satellite Science Requirements

(Termed “Level -1” or “L1”)

- DPR: *quantify rain rates* between 0.22 and 110 mm hr⁻¹ and *demonstrate the detection of snowfall* at an effective resolution of 5 km.
- GMI: *quantify rain rates* between 0.22 and 60 mm hr⁻¹ and *demonstrate the detection of snowfall* at an effective resolution of 15 km.
- Core observatory radar estimation of the *D_m to within +/- 0.5 mm.*
- At 50 km resolution, instantaneous rain rate estimate with *bias and random error < 50% at 1 mm hr⁻¹ and < 25% at 10 mm hr⁻¹, relative to calibrated GV*

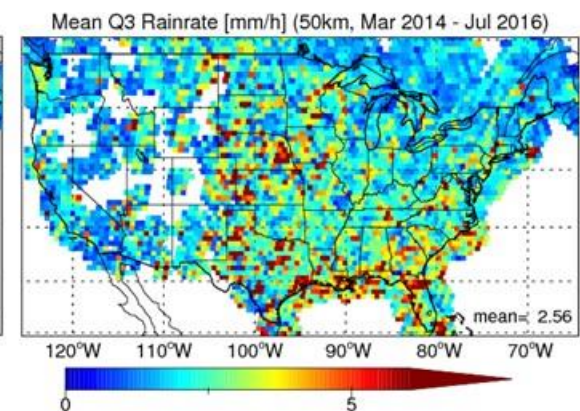
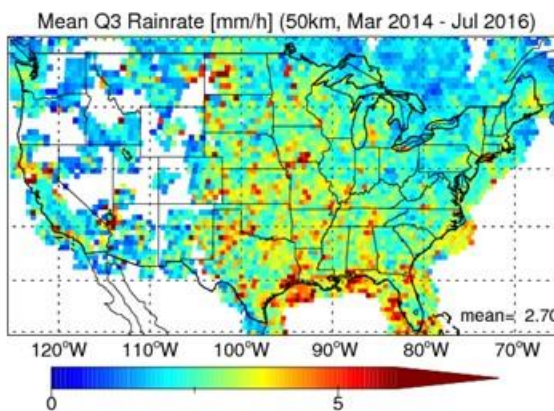
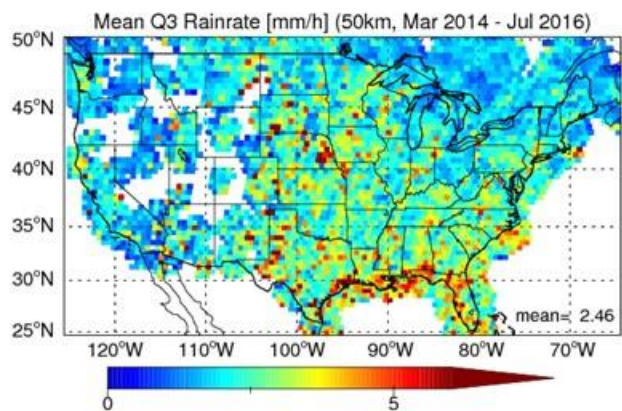
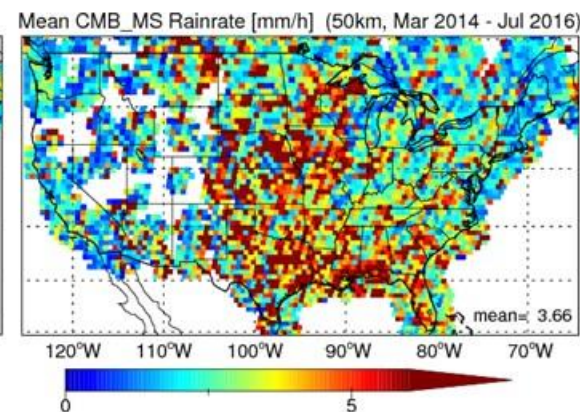
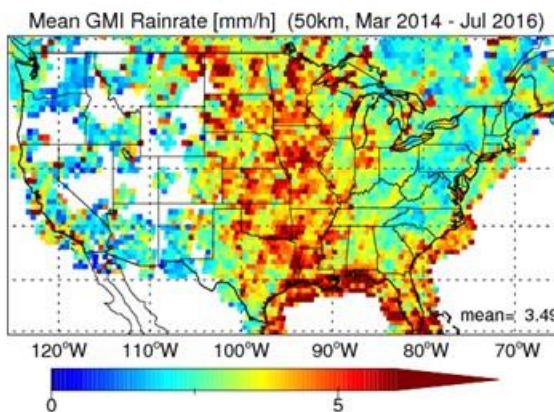
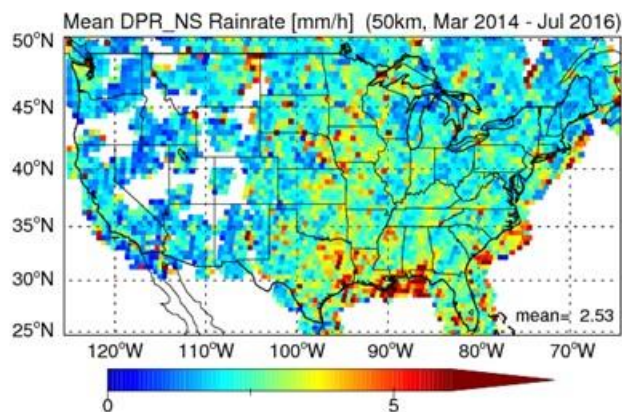


CONUS Mar 14 – July 16: GV MRMS vs. DPR/Combined
Conditioned on 0.2 mm/hr threshold at FOV

DPR NS

GMI-GPROF

Combined MS

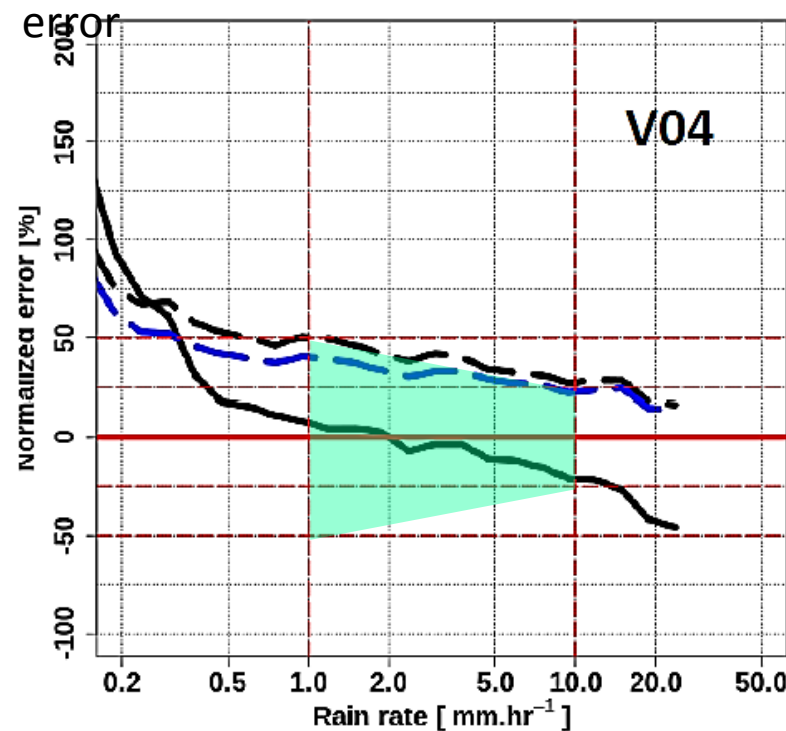
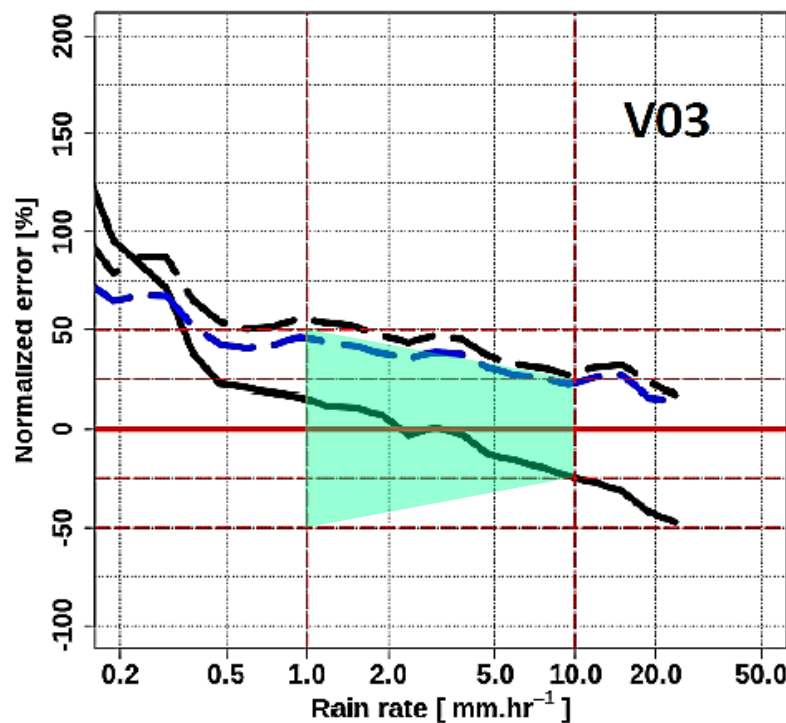


Which products “compare” the best with MRMS? DPR NS (DPR MS and KuPR, similarly)
Relative trends generally consistent with global behavior over land

L1-Required 50 x 50 km² area

(footprint matched, then averaged to 50x 50 km²)

Need 50%(25%) @ 1 mm/hr (10 mm/hr) bias and random

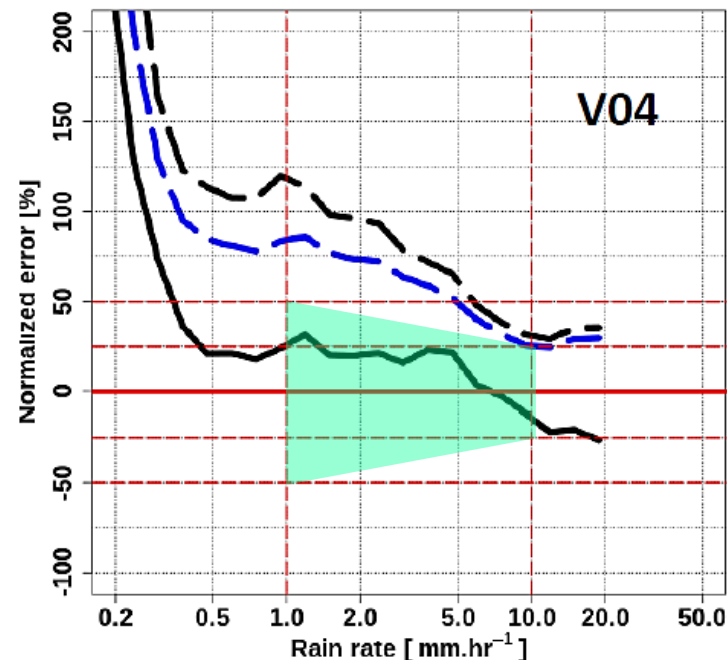
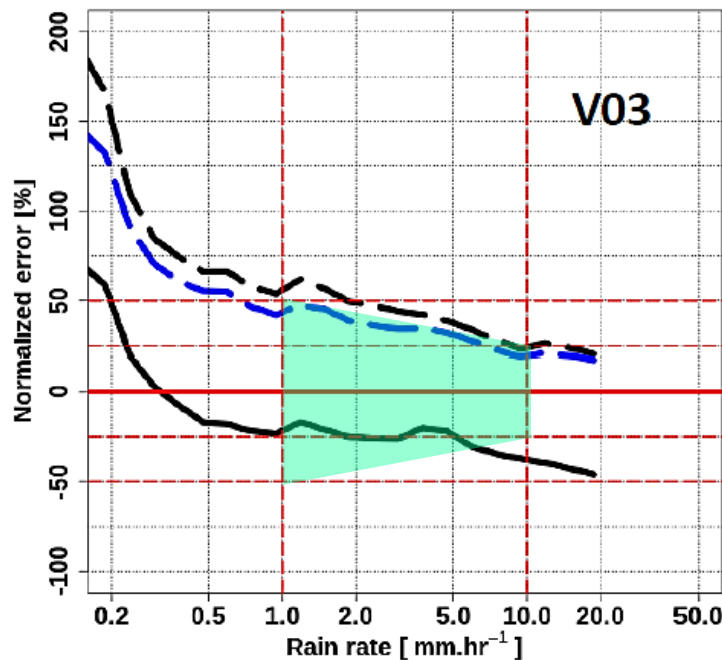


— Bias at 50 km resolution

— RMSE at 50 km resolution

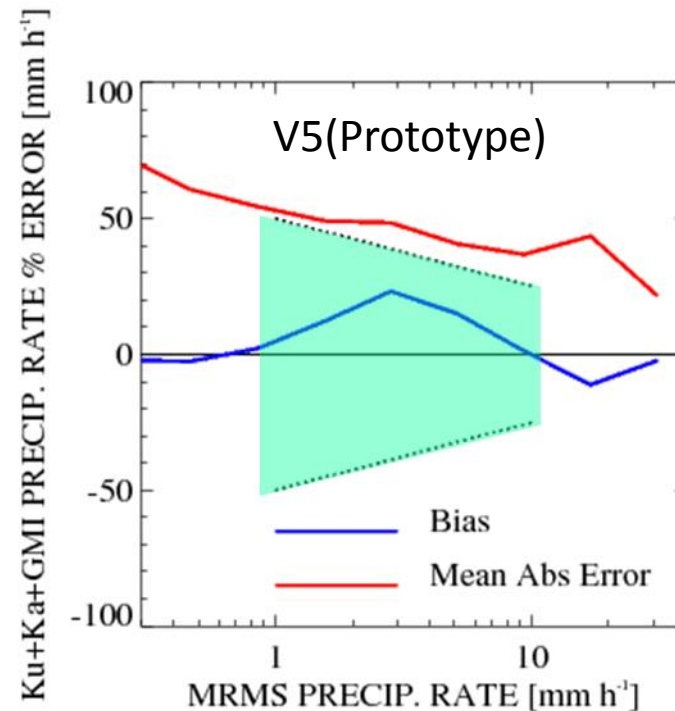
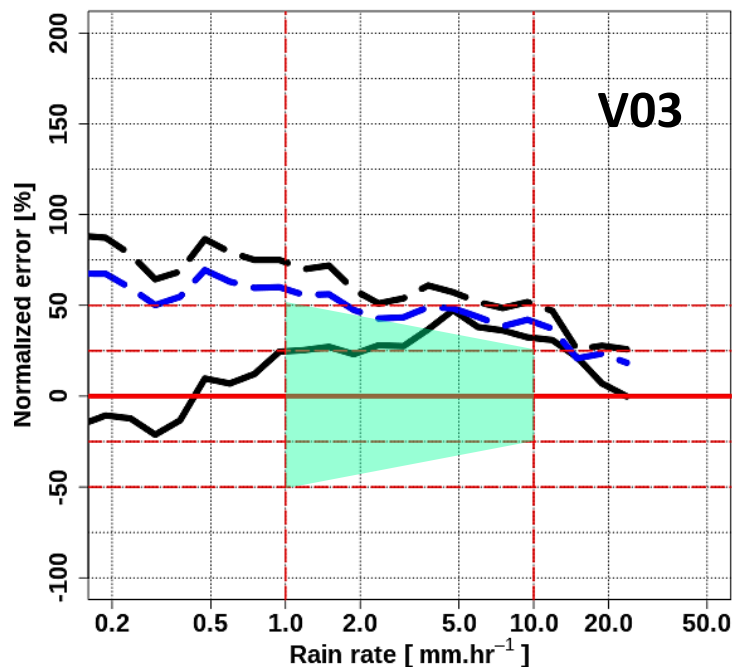
— MAE at 50 km resolution

L1-Required 50 x 50 km² area



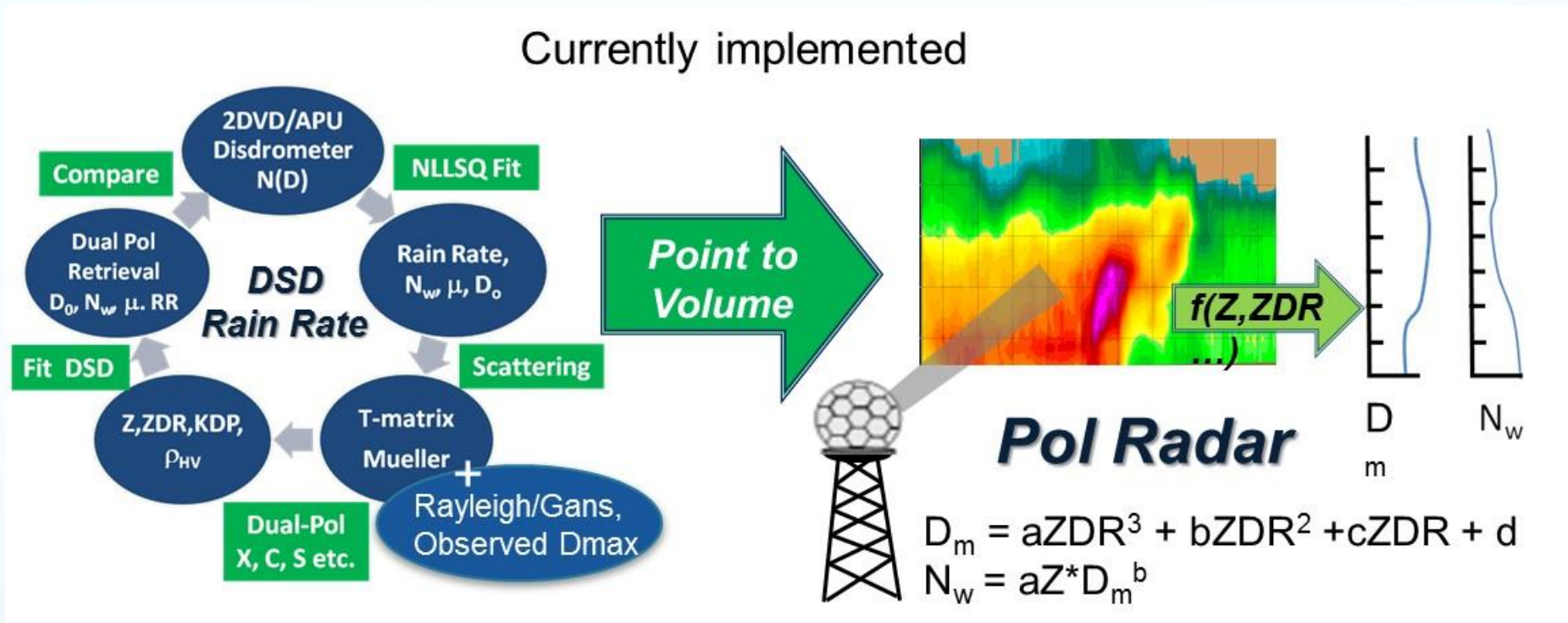
- Bias at 50 km resolution
- RMSE at 50 km resolution
- MAE at 50 km resolution

L1-Required 50 x 50 km² area



- Bias at 50 km resolution
- RMSE at 50 km resolution
- MAE at 50 km resolution

DSD: GV Disdrometer and Polarimetric Radar



Minimum $D_m \sim 0.6$ mm; Sensitivity of approach at large D_m/ZDR due to limited sample of large drops/high ZDR (also modeling challenge)

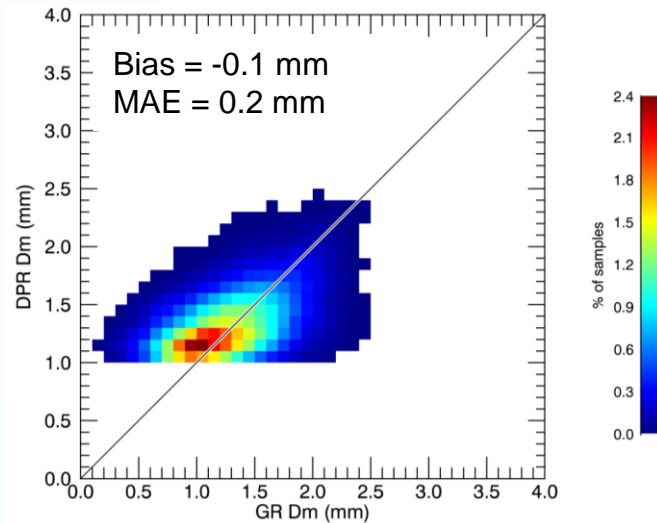
For span of validity, when tested on independent data:
Bias 1 - 10%, MAE 7 -15%

Val. Network GV-DPR matchups for broader view of DPR (NS) D_m

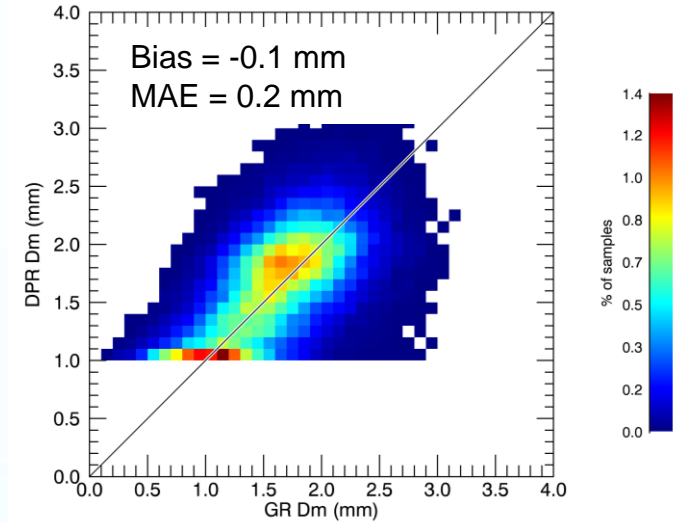
Recall that L1 says “.....to within +/- 0.5 mm”.....

GV and DPR similar, marked change in convective large D_m mode in V4

V3

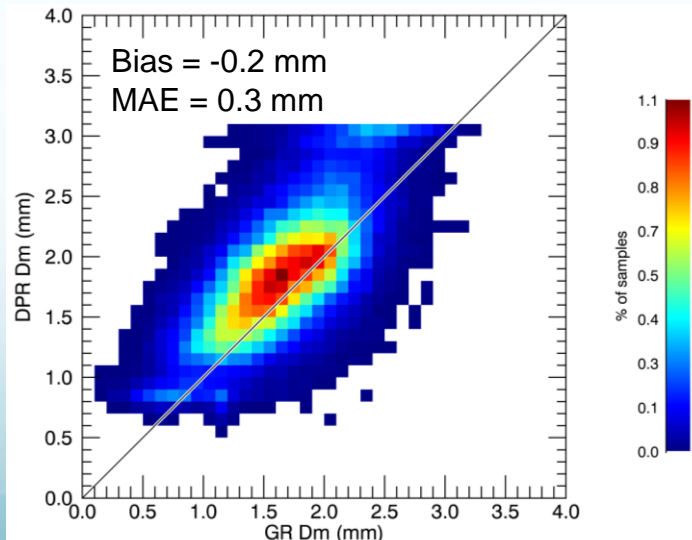
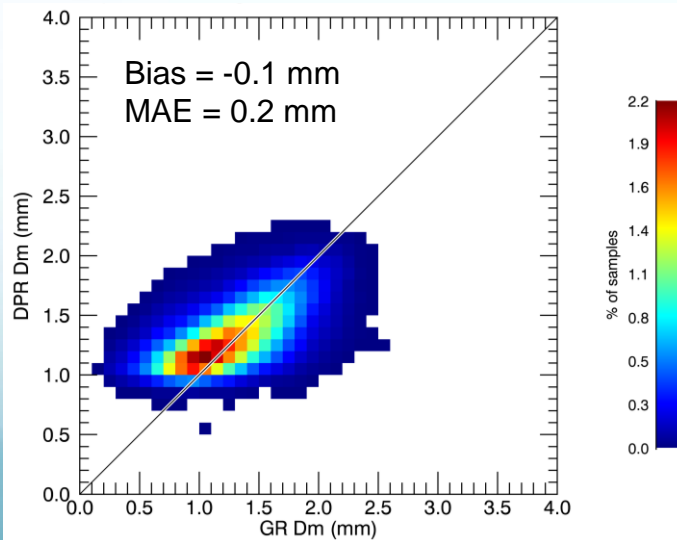


Stratiform



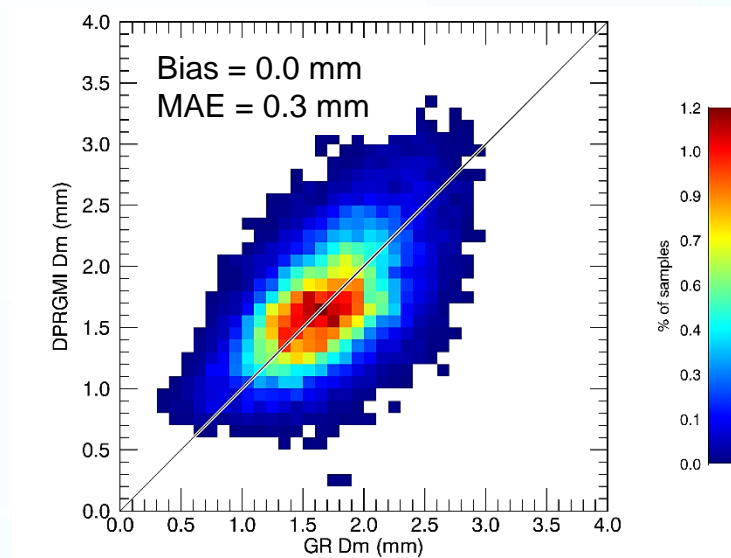
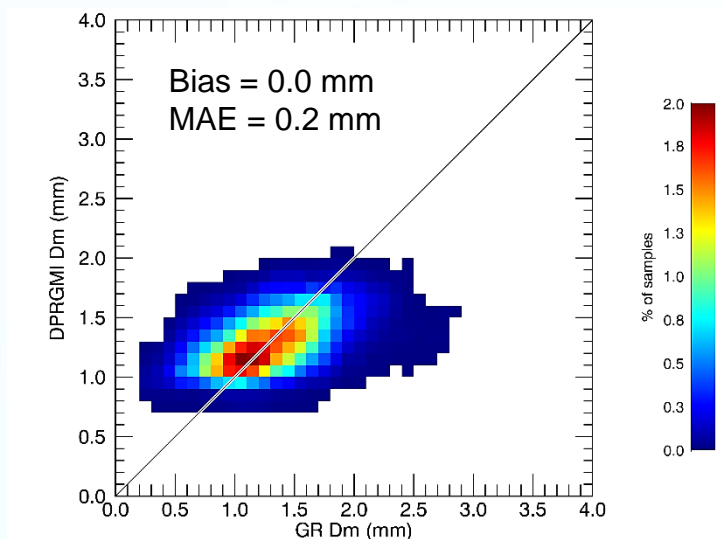
Convective

V4



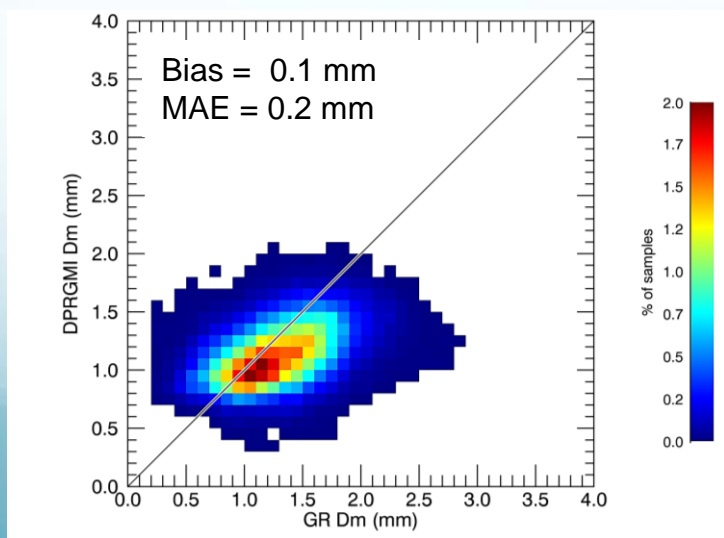
Combined (MS) and GV- good agreement; convective large D_m mode not present.....

V3

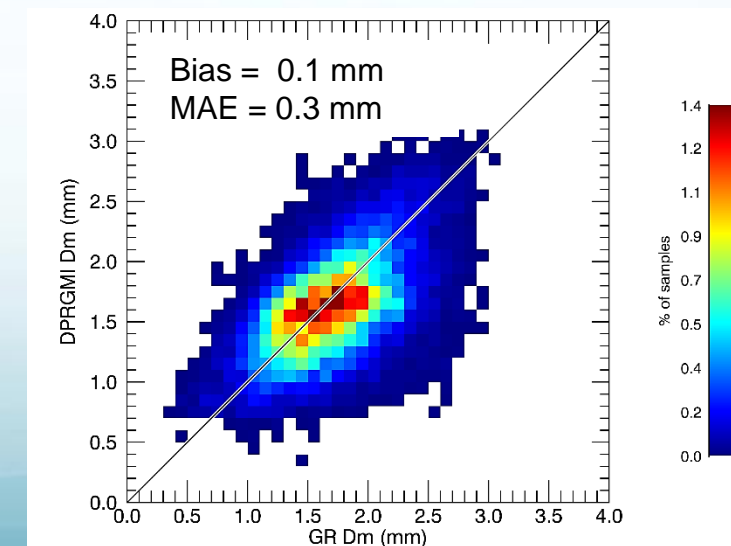


Stratiform

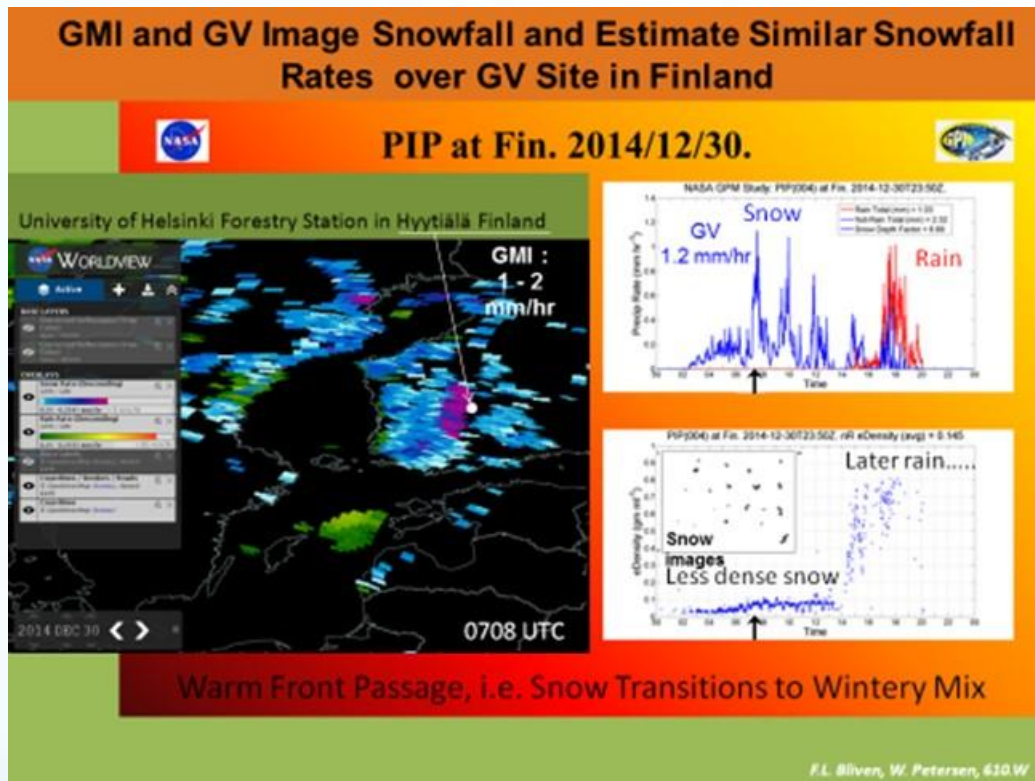
V4



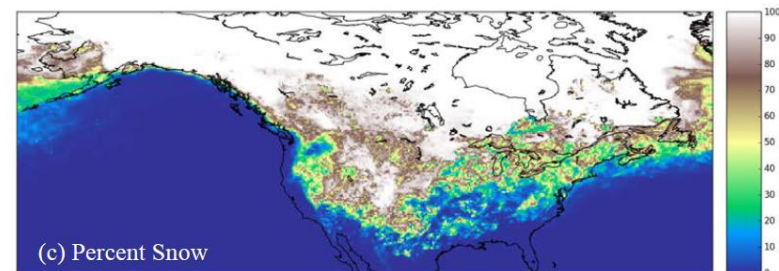
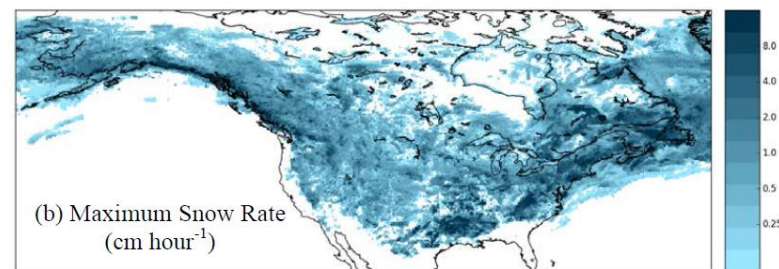
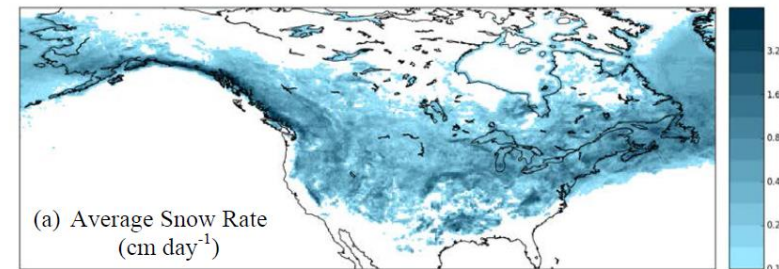
Convective



SNOW: “Demonstrate *Detection*”



GMI and PIP Instantaneous snowfall rates over Hyytiälä, Finland GV site

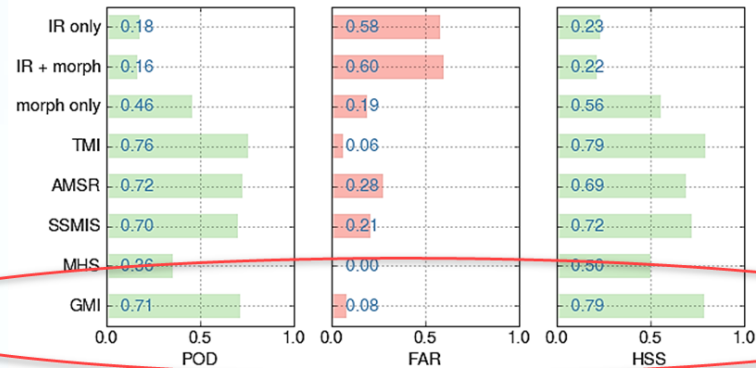


GMI GPROF Seasonal Snow
Winter Dec, 2014-Feb. 15

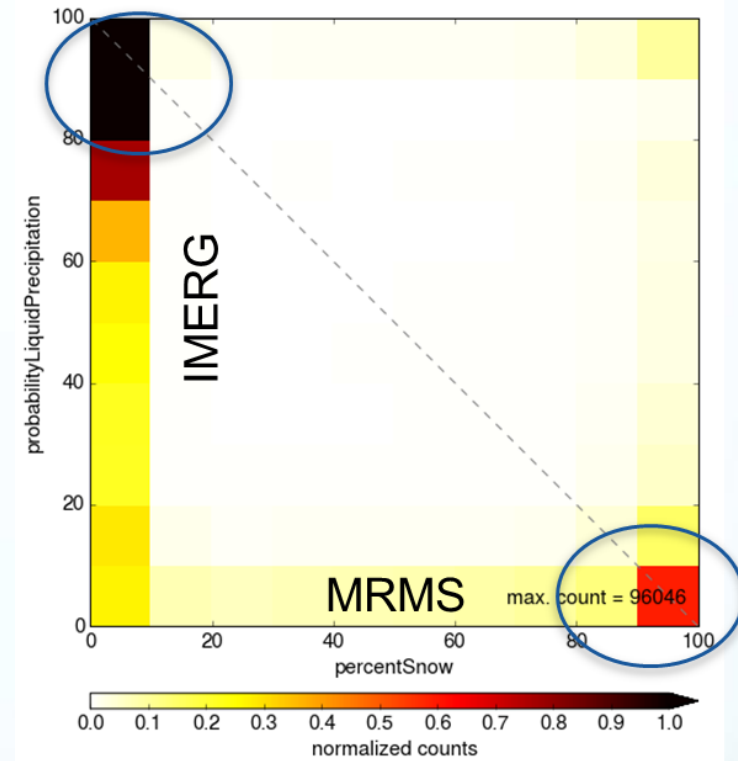
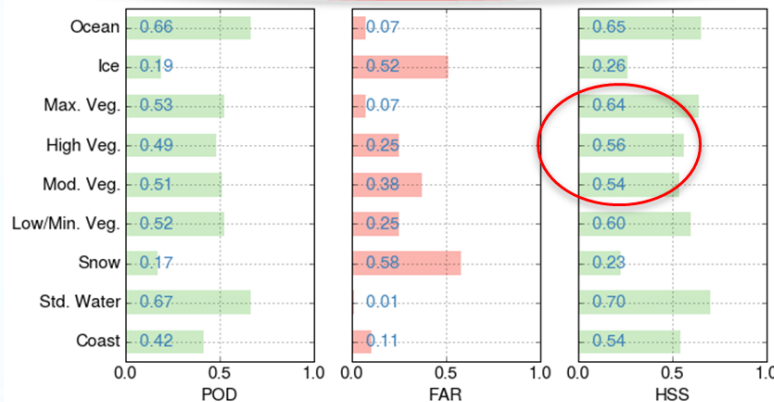
Skofronick-Jackson et al. 2016, submitted

Snow “detection” at FOV: MRMS, Passive Microwave and IR from IMERG

Platform



Snow Detection Land Surface Sensitivity

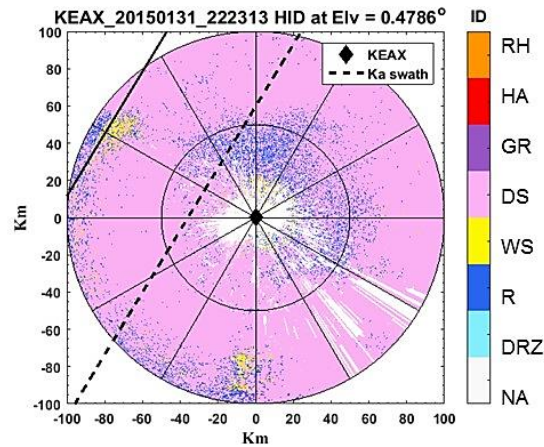
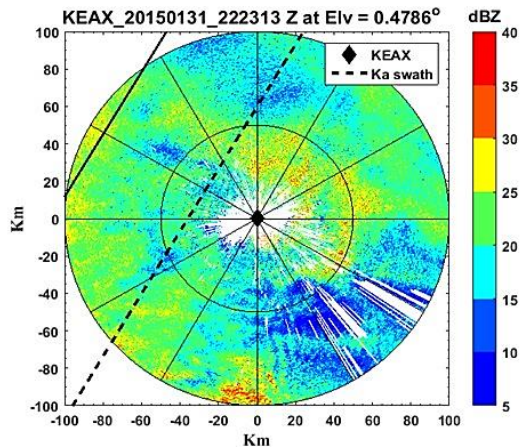


- Snow “detection” is ambiguous....doesn’t define what we do or do not detect”
- Mean “miss” SWER based on fixed MRMS Z-S relationship
- Land ~1-1.4 mm/hr
 - Ocean SWER ~0.57 m/hr

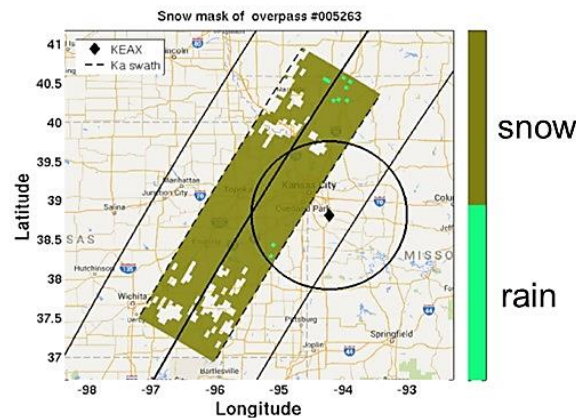
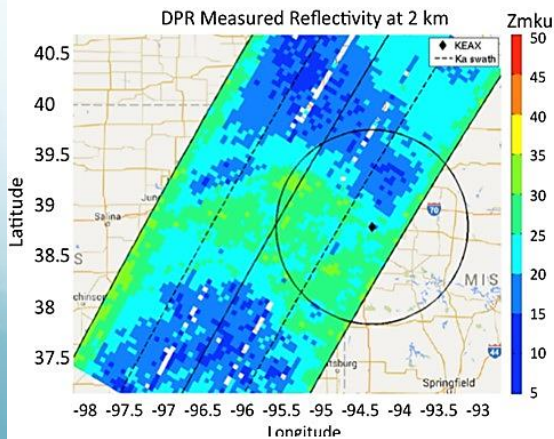
DPR Snow Detection

V4: Precip > 0 for both MRMS and DPR (CMB) MS FOVs, majority of MRMS beam heights < 1.5 km

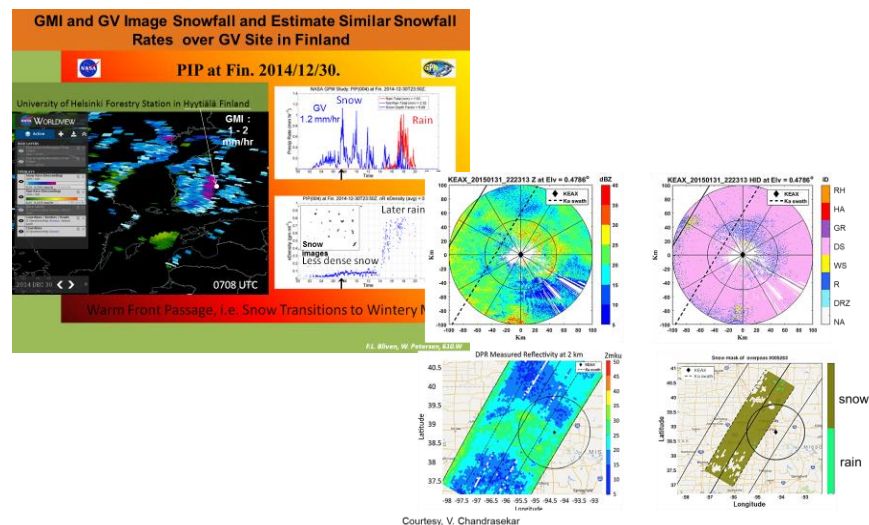
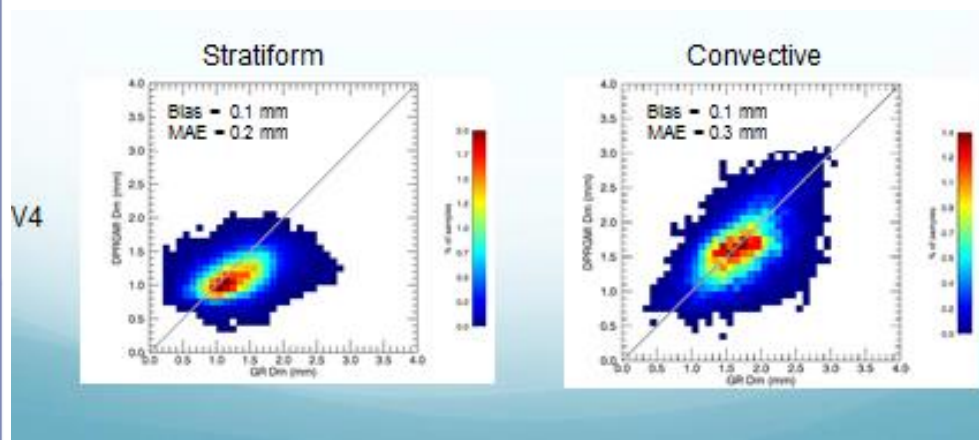
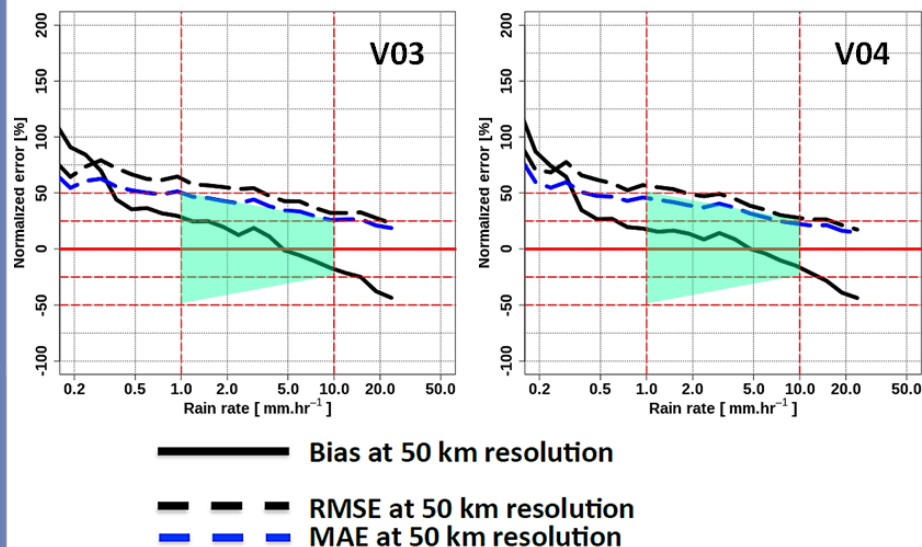
Using PhaseNearSurface (surfLiqRateFrac): **POD 87% (89%), FAR 9% (11%)**



**Version 5: New
DFRm snow-Index
(Le and Chandra):**
Validation using 88D
HID algorithms
against DPR MS

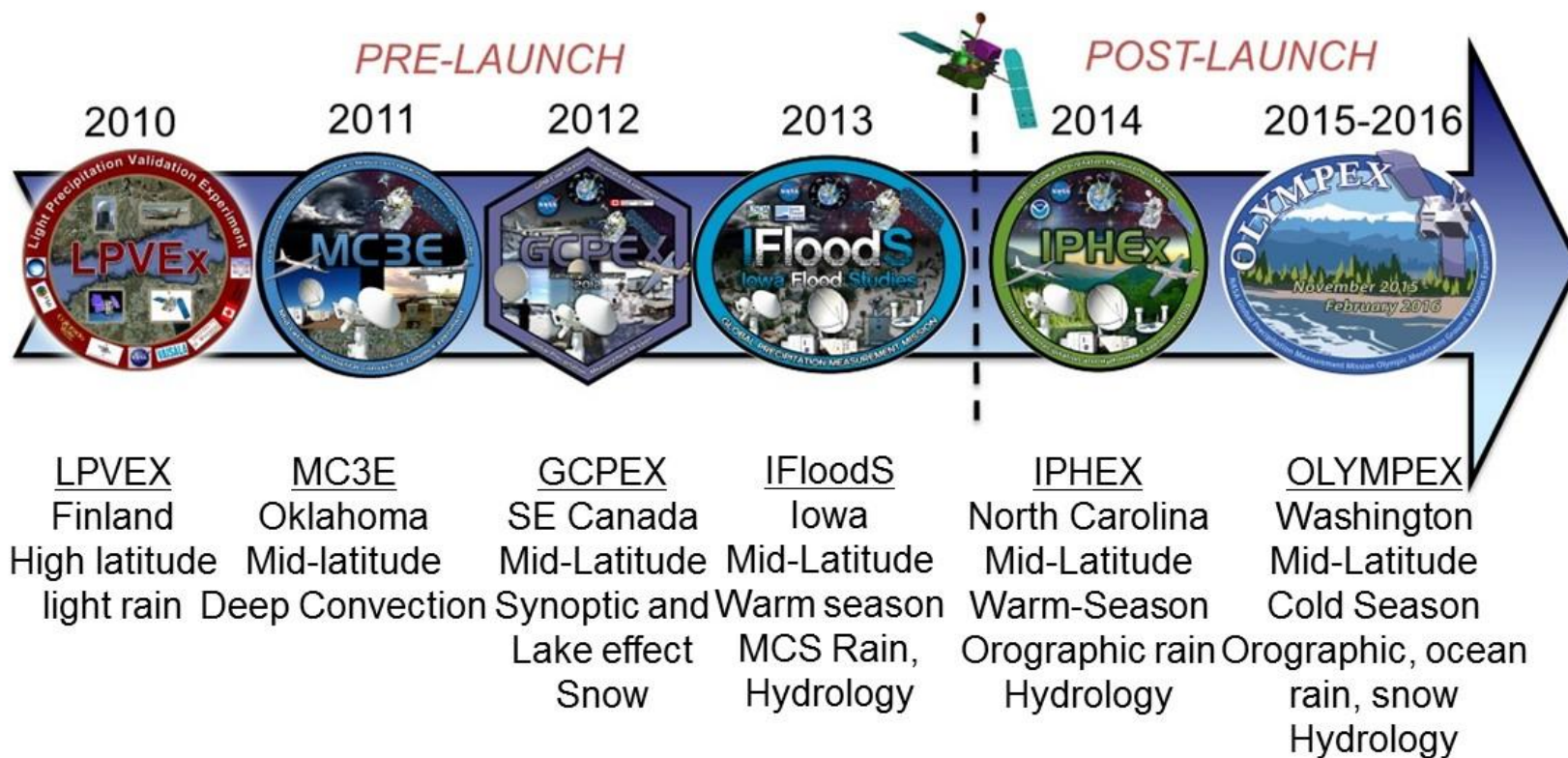


Courtesy, V. Chandrasekar (CSU)



- Datasets and basic approaches developed. Tweak, finalize, finish running analysis over mission to date
- Mission Review
- V5 products?

GPM GV Lead / Co-Lead



GV Contributions to International Partner Campaigns



2006/07 Canada
Lake effect and
synoptic snow



2010, Brazil, INPE/CPTEC
Tropical warm rain

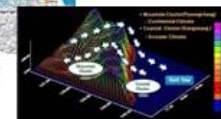


2012 EU- France/Italy,
orographic rain



ICE-POP

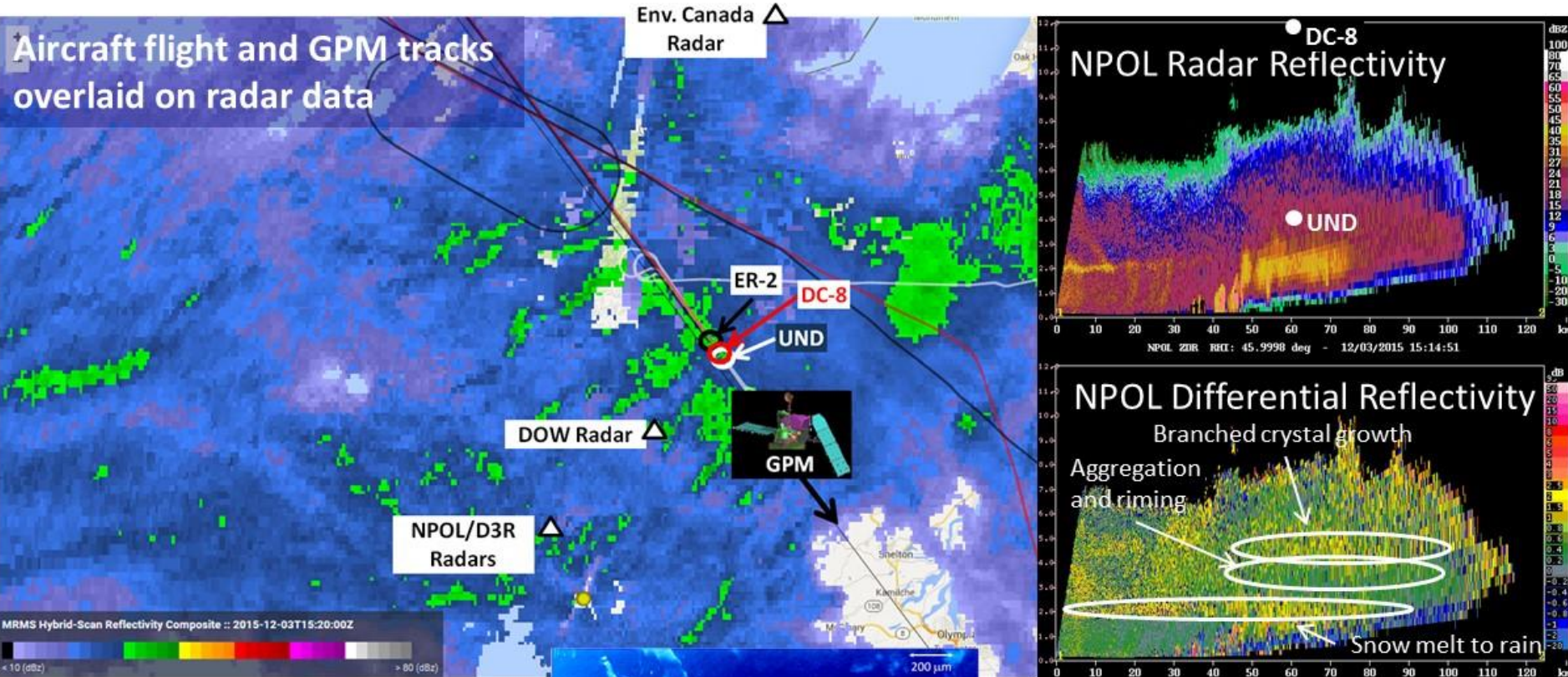
2018, KMA- Korea
orographic snow



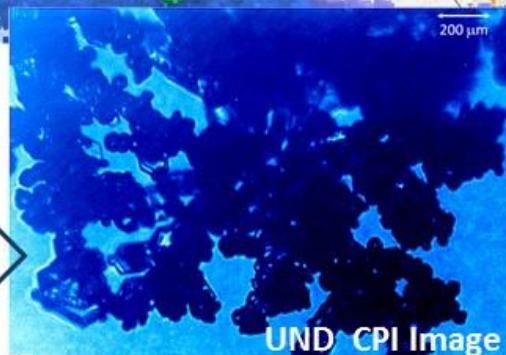
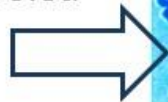
Process and GPM Algorithms

OLYMPEX Conducts first ever 3-aircraft stack (DC-8, ER-2, UND Citation) directly under the GPM Core satellite track within multi-ground-based polarimetric radar coverage

12/3/2015: A complex heavy precipitation event over the Olympic Mountains



UND Citation cloud particle imager (CPI) observation, 4 km altitude. Indications of rimed (supercooled liquid water), branched and aggregated snow.



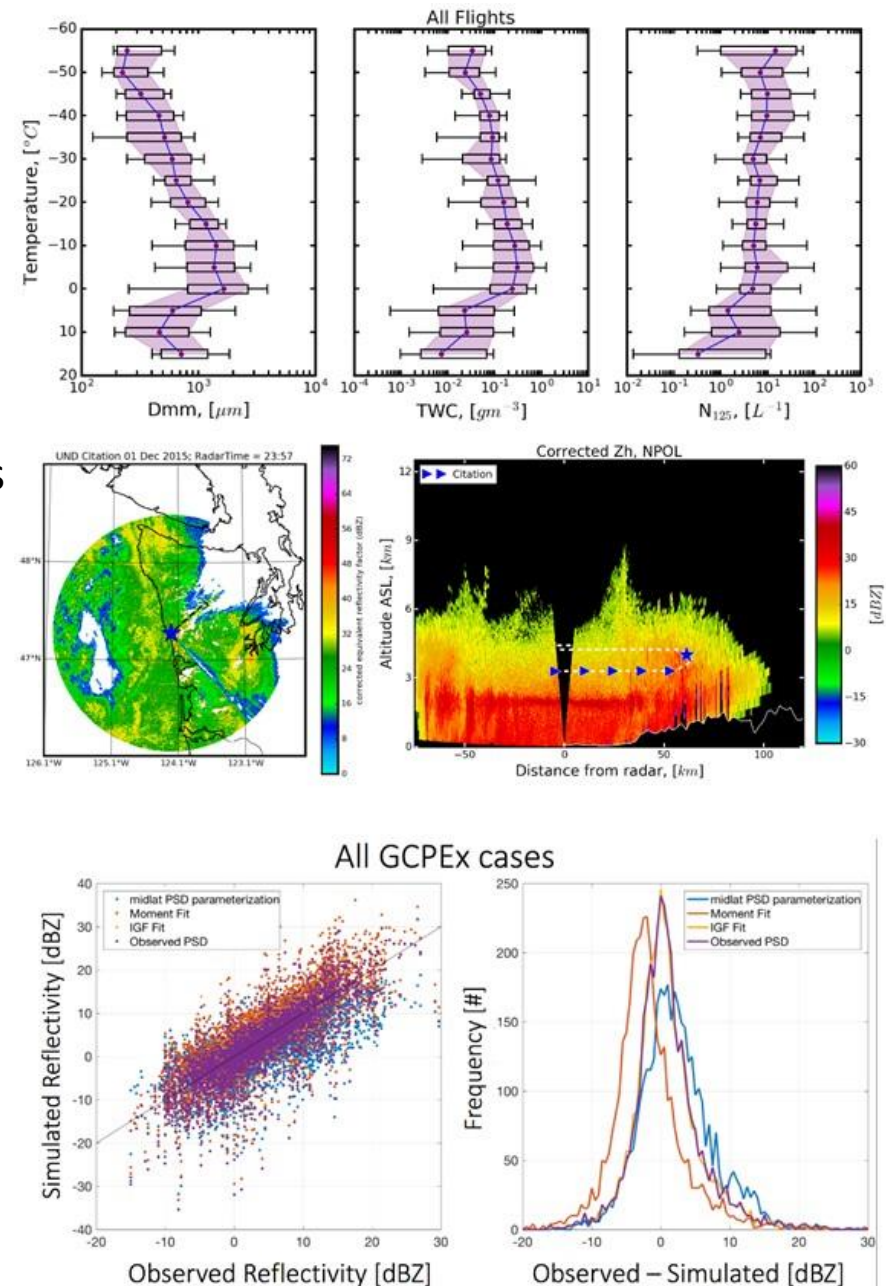
NPOL Radar vertical cross-sections across GPM satellite/aircraft tracks indicating snow crystal growth and aggregation process to make rain below

Building the “column” – PSD working group

- **GPM retrieval algorithms need accurate assumptions in the vertical**
- GPM needs to move beyond “convective vs. stratiform” thinking - *What are the “regimes” in global precipitation in terms of quantities algorithms need?*
 - Particle habit, size distributions, fall speeds
 - Scattering properties
 - Riming/supercooled water/melting

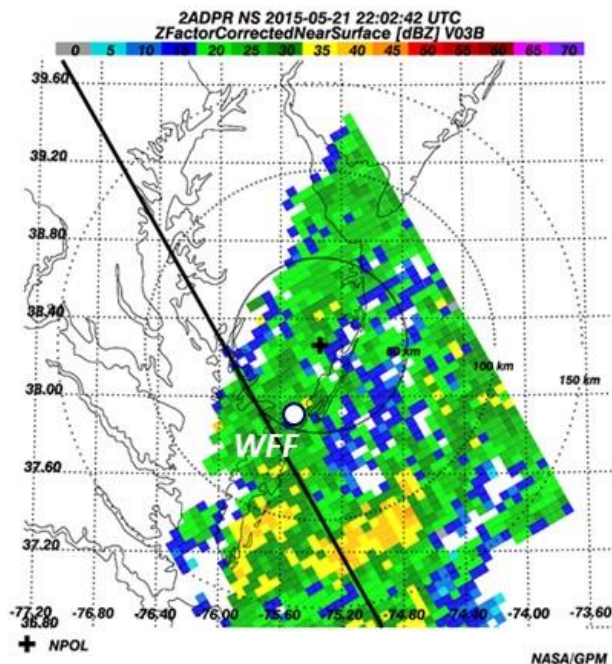
How can GPM-GV address these unknowns?

- Statistical analysis of multi-campaign data and long term measurements to determine “regimes” and spatial and environmental correlations
- Process studies of campaign data using combined vertically-resolved and surface in situ measurements, and profiling/scanning radar and radiometer data
- End-to-end error characterization exercises. How do our assumptions impact retrievals?

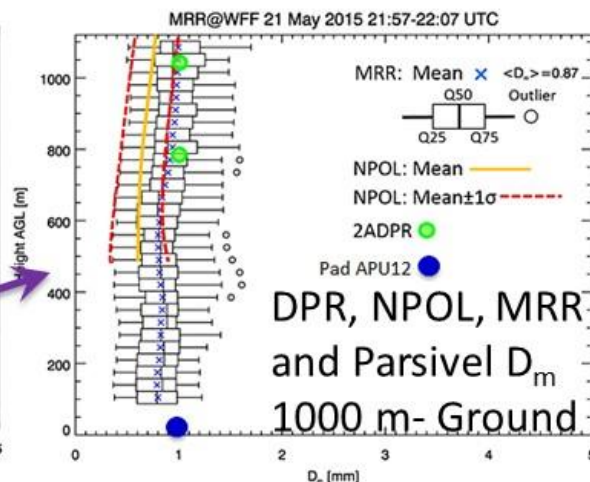
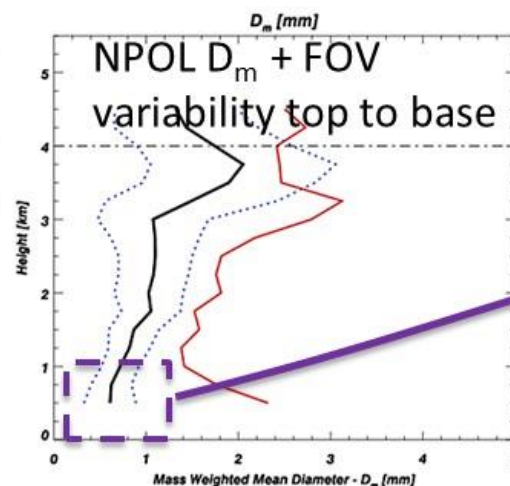
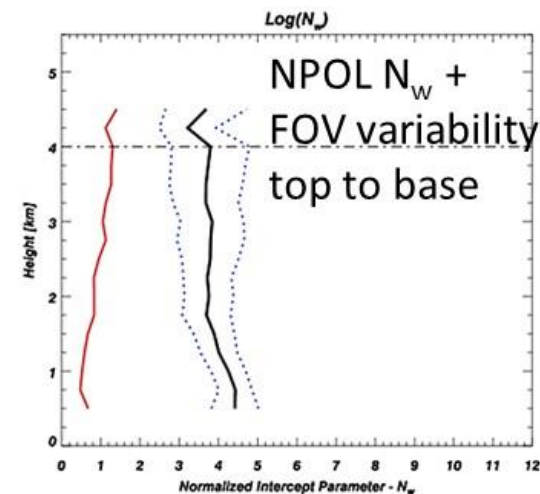
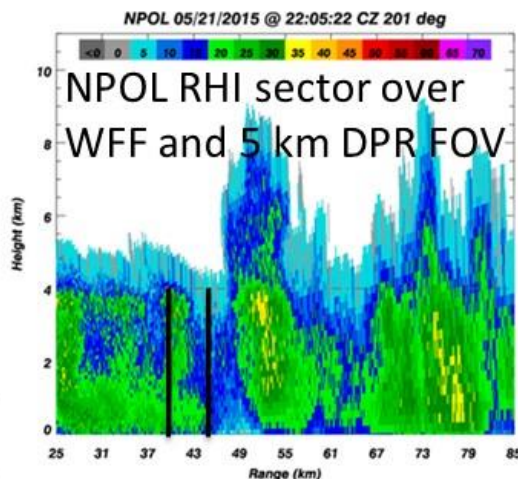


Prolific GV data sets exist from field campaigns and Wallops GV Site.....

2ADPR NS Over WFF



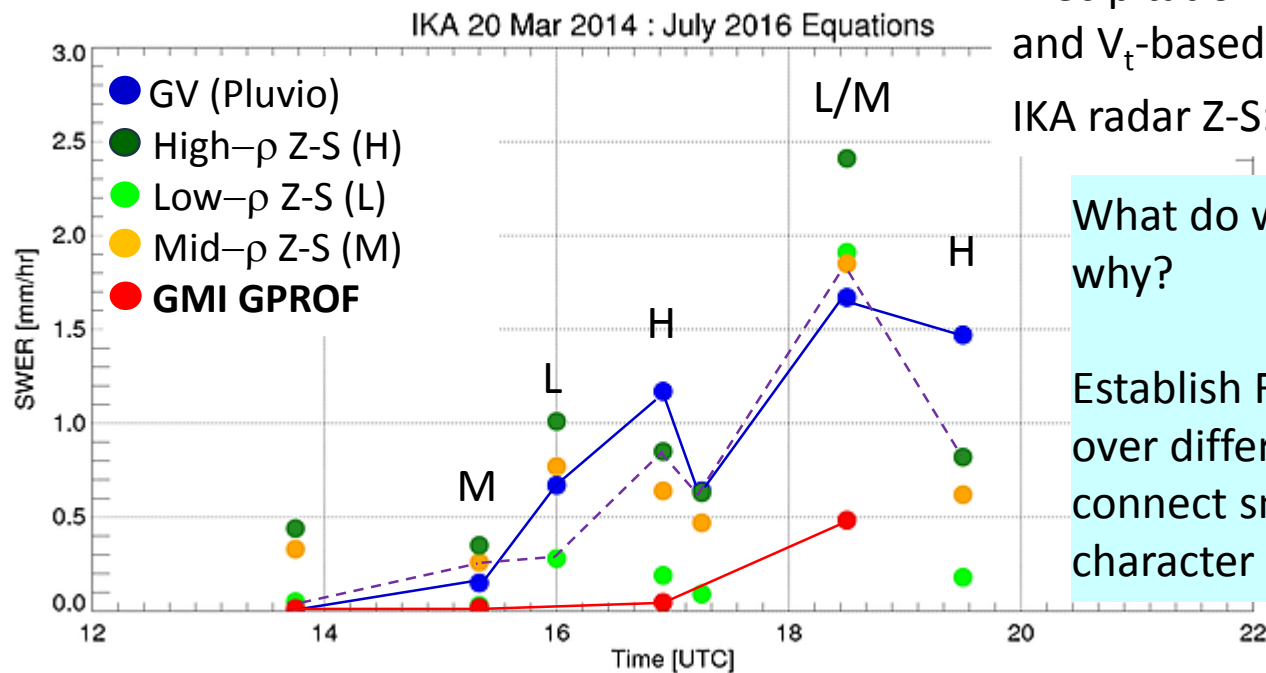
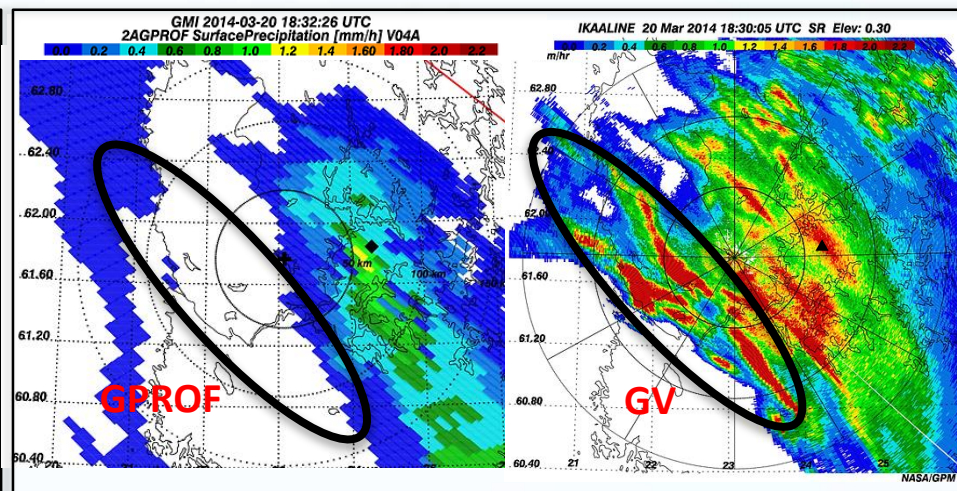
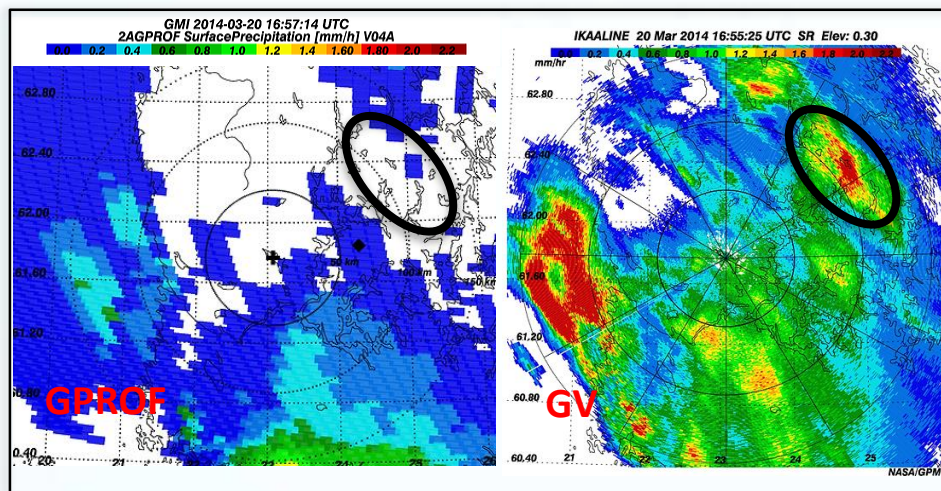
How does intra-FOV variability impact retrievals? Do DPR and GV agree, ground-up?



DSD consistency between DPR, NPOL and ground instruments- with observed intra-FOV variability

Snow: Work to Improve Space-Based *and* GV SWER Estimation

Finland, Hyytiala/SNEX Intra-event ρ -Variability w/GPM Overpass



Precipitation Imaging Package (PIP)/Pluvio and V_t -based ρ -D for case-specific Z-S

IKA radar Z-S: 0.3° tilt; 500 m AGL

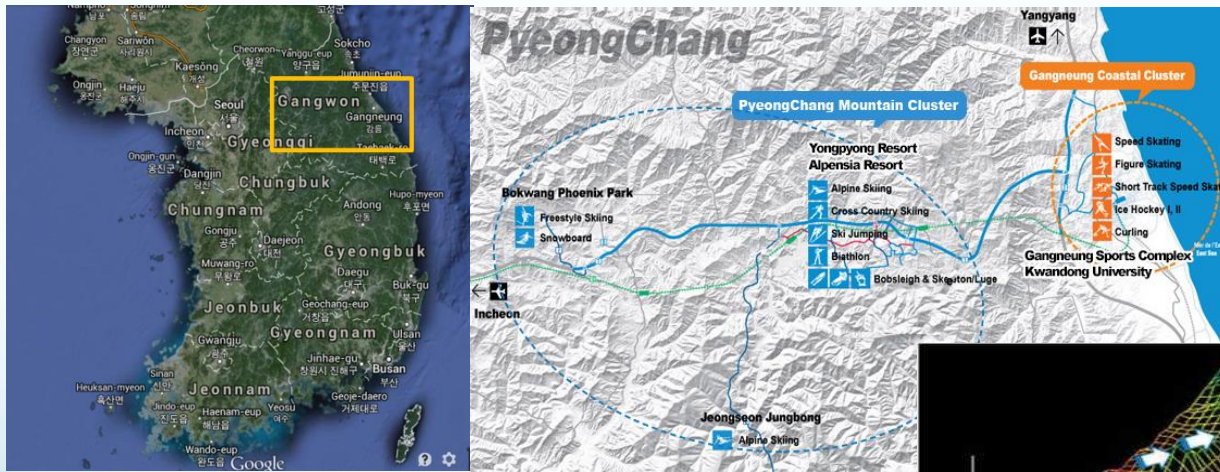
What do we or don't we detect and why?

Establish FOV detection thresholds over different land surface types *and* connect snowfall rate to physical character

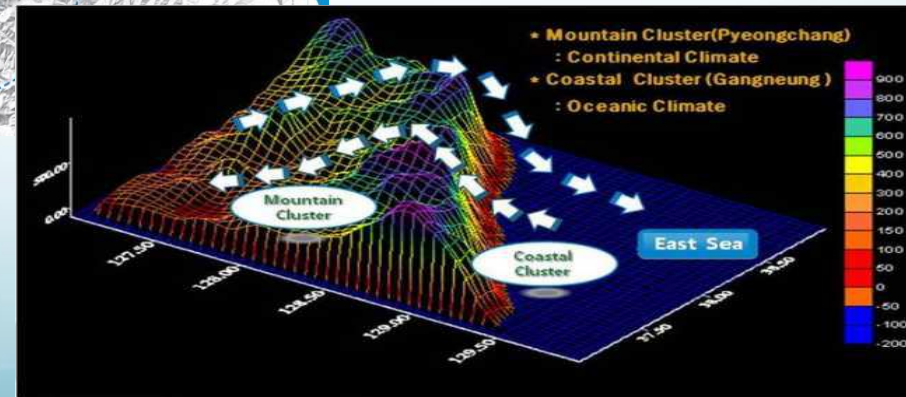
ICE-POP Snow Experiment 2018

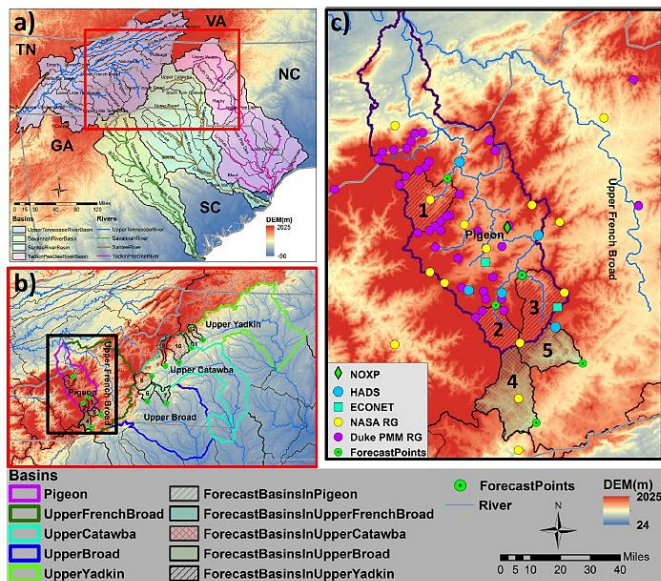
International Collaborative Experiment – PyeongChang Olympics Paralympics

- Winter extreme weather forecast demonstration (research and real-time decision support) and precipitation process research (e.g., measurement and prediction of orographic/terrain forced snow)
- KMA Lead, international investigator team
- GPM GV: D3R Radar, PIP, Pluvio, Parsivel deployments; GSFC/MSFC NUWRF Effort
- Work up: 2016-17; **2018 Intensive Observation Period (IOP)** with 2018 Winter Olympics
- Coastal (Gangneung) and PyeongChang Mountain clusters: High res. international forecast models, dense surface observations (dual-pol/multi-freq. radars, gauges etc.), NIMR microphysics aircraft



“Modes” of snow: Heavy orographic via mix of migrating westerly cyclones or easterly “backdoor” cold fronts (anticyclones) with key adjacent ocean moisture fluxes, terrain gradients.





J. Tao et al., 2016
J. Hydrology

- Improved QPE using IPHEX field data with Q3;
 - Improved NUWRF forecast of storm location/timing with GMI and SSMI/S satellite radiance assimilation
 - Improved streamflow forecasting- with large improvement enabled by additional assimilation of stream flow in the DHCM
 - Result sensitive to basin scale
- Tie in more physics and use approach for IFloodS, OLYMPEx or other similar data?
- Applications extension/expansion!

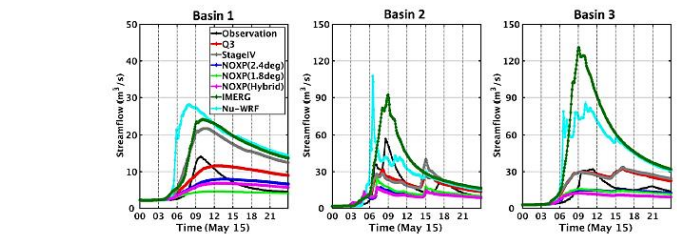
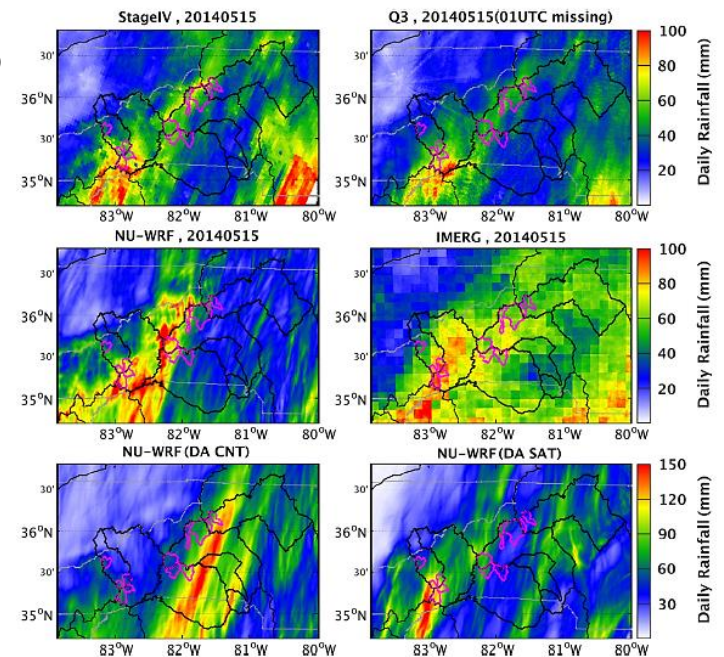


Fig. 8. Forecast/hindcast results on May 15, 2014 using multiple QPEs (Q3, StageIV, NOKP data at 1.8° and 2.4° elevation angles and the hybrid data, and IMERG) and QPE from Nu-WRF in headwater catchments in the Pigeon River Basin (Basin 1–3, from left to right).

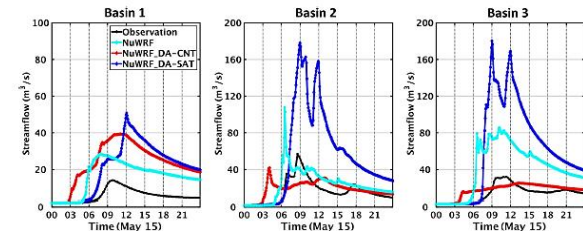


Fig. 9. Forecast results on May 15, 2014 using the improved NU-WRF QPEs by assimilating conventional ground-based observations (DA-CNT), and assimilating satellite-based data (DA-SAT) (GPM GMI and SSMIS precipitation-affected radiance) also for the three headwater catchments in the Pigeon River Basin (Basin 1–3, from left to right).

Thanks!



Footprint and Area Selection

- 5 km DPR / 15 km GMI footprint “effective” resolution assumed
- 50 km x 50 km averages (of footprints), but also computing footprint bias and scaled random error (5 km/15 km footprints to 50 km scale; Steiner et al., 2003) to mitigate small sample numbers of 10 mm h⁻¹ rain rates experience over in 50 km grid boxes.

Instantaneous rain rates for “reference”

- MRMS Gauge-bias-adjusted radar subset over CONUS and central/southern U.S.
- Radar Quality Index = 1; NUBF > 80% FOV fill, 25% of 50 km box filled with > 0 mm/hr
- KwajPol/other sea-based radars (e.g., Middleton Island, AK) triplet of dual-pol estimators
- GPROF (GMI) Thresholds: currently use POP > 40% to ensure > 0 rain rates
- 5th/95th percentile outliers removed

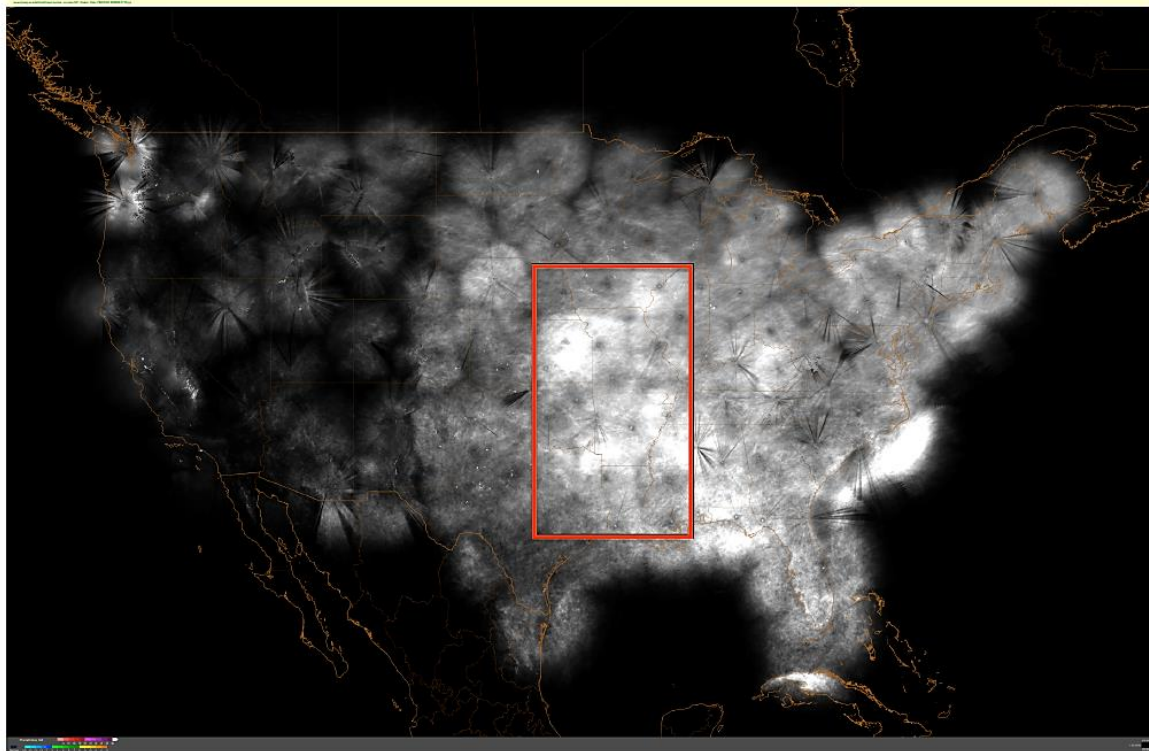
DSD- Drop Size Distribution (D_m)

- GV Disdrometer-based polarimetric radar retrievals of D_m - scaled up to Validation Network ~60-radar subset of U.S. WSR-88 dual-pol network.
- Multiple regimes (field campaigns and long term sites); data subset used in error testing

Snow (Detection)

- MRMS constraint of height off surface- Datatype 3.0 (< 1.5 km); precip type id= snow.
- GMI POP 40%, <50% Liquid precip fraction (also Combined Alg.); DPR “phase near surface”
- Snow index and METAR or like database

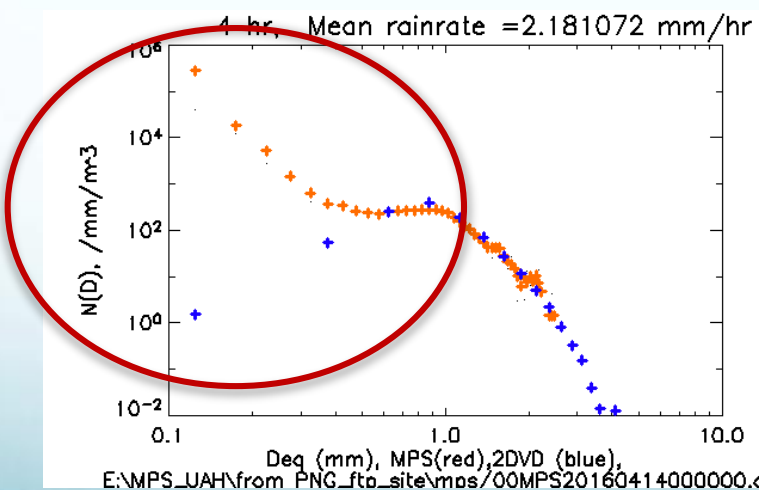
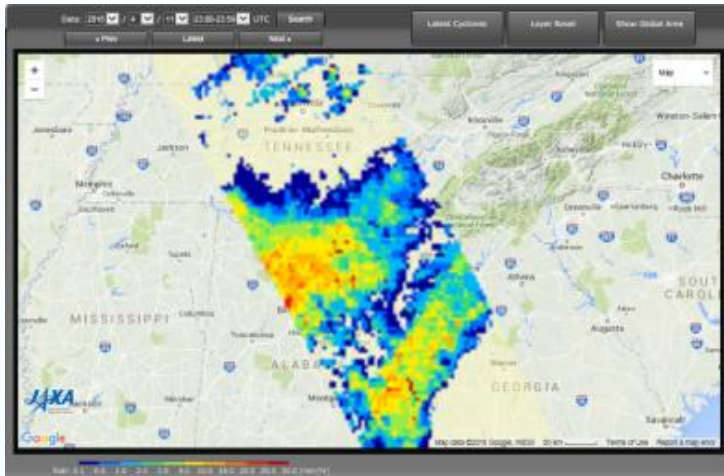
MRMS best observation areas



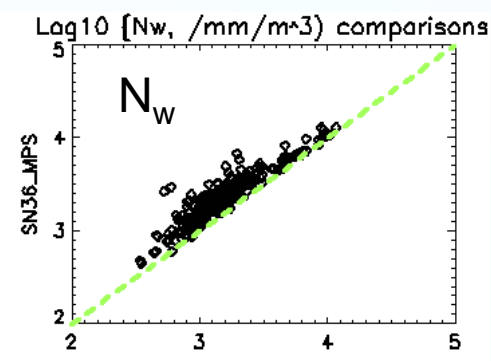
Gamma assumptions?
GV-measured rain DSD limitations.....small drop impact?

DMT MPS vs. 2DVD Disdrometer

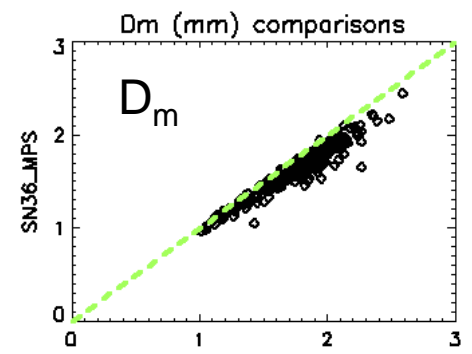
April 11 2016



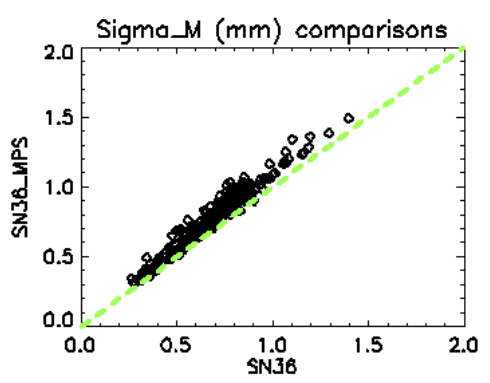
MPS



MPS



MPS



2DVD

Ocean: Kwajalein(KWAJ) and Middleton Island AK (PAIH)

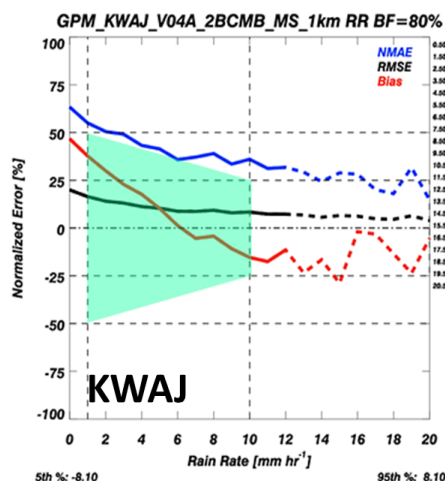
March 2014 – June 2016

Footprint stats with
RMSE scaled to 50 km

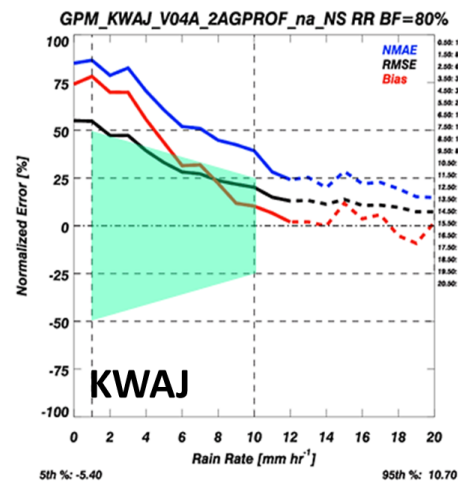
Hard to get heavier rates
in sufficient numbers at
PAIH, but within L1
requirements otherwise

*DPR and KuPR both within L1
requirements at both locations

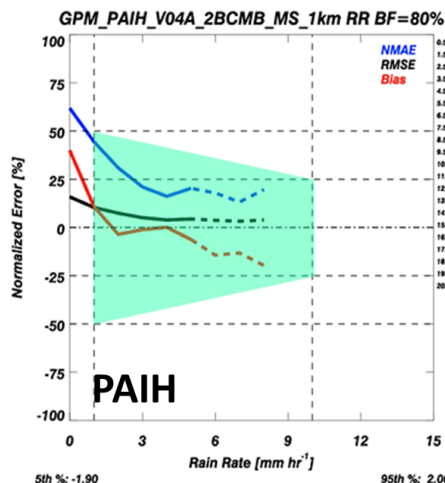
2BCMB MS



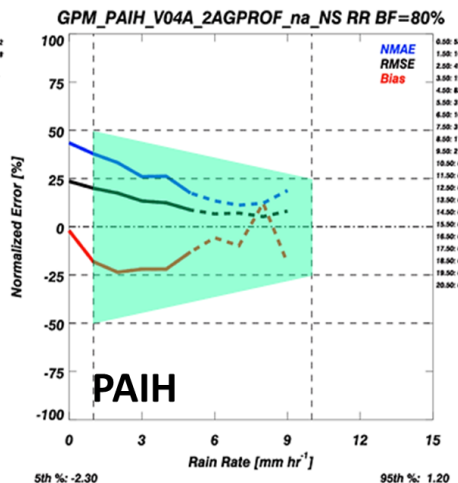
2AGPROF



2BCMB MS



2AGPROF



—— BIAS

----- FOV MAE

----- 50x50 Scaled RMSE